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TITLE: DEVELOPMENT OF R. AND D. PROJECT DESCRIPTIONS RELATED TO NOVA SCOTIA GOLD DEPOSITS

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OBJECT OF REPORT

The object of the report is to develop R. and D. Project descriptions to benefit the establishment of a viable Nova Scotian gold industry. It has been necessary for the writer to:

1. Review the historical data of Nova Scotian gold processing in the quartz veins contained in the Meguma Group.
2. Discuss the background and aims of the Canada/Nova Scotia Mineral Development Agreement with personnel from CAN MET, GSC and MPS with reference to gold activity in Nova Scotia.
3. Meet with personnel at present active in the gold extraction industry in Nova Scotia. Those included N. S. Mines and Energy personnel as well as mining executives, engineers, and geologists.
4. Visit Nova Scotian research facilities and gold processing plants to determine present physical plant resources.
5. Use his knowledge not only of Nova Scotian gold processing through operations in which he took part, but also his awareness of the overall current world gold processing and economic developments.
6. Visit research facilities and personnel with experience in areas of the proposed R. and D. projects.

Some criteria used to develop R. and D. project descriptions were:

1. to be of direct aid in developing N. S. gold processing.
2. to apply existing technology to improve process economics.
3. to assist potential N.S. gold producers.
4. to apply new technology to meet the specific problems of N.S. gold occurrences.
5. to recommend the use of N.S. research facilities and staff where possible to conduct the proposed R. and D. projects.

SUMMARY OF RECOMMENDED R. AND D. PROJECTS

The three main areas for R. and D. funding are:

1. to develop a method to improve the extraction of gold from sulphides and create a by-product for sale namely arsenic trioxide
2. to sample and test material from two potential gold resources in the Province
3. to initiate mineralogical studies in order to define the distribution of gold in the Meguma Group

Proposed for R. and D. funding are:

1. Fluid bed two stage roasting of auriferous sulphide concentrates followed by calcine leaching to recover gold values and an arsenic trioxide by-product.
2. To study the pressure hydrometallurgy of samples of auriferous sulphide concentrates using known processes to improve subsequent gold recovery by cyanidation.
3. To study the oxidative atmospheric hydrometallurgy of samples of auriferous sulphide concentrates using known processes to improve subsequent gold recovery by cyanidation.
4. To study bacterial leaching of: a) sulphide concentrates prior to cyanidation and b) gravity tailings and old gold tailings to remove sulphur and thus render the gold amenable to recovery through heap leaching techniques.
5. Mineralogical studies by Image Analysis on selected samples of the Meguma Group to establish the occurrence and distribution of gold and related materials.
6. To sample, examine and recover gold from lake bottom residues, made up of old glacial till, basal till from the 15 Mile Stream area, and river sediments .

The suggested time required to complete the first stage of such an R. and D. programme is 12 months.

BRIEF HISTORY OF N.S. GOLD PRODUCTION

The history of gold production in Nova Scotia from the first discoveries in the 1860's has been of numerous small producers. Gold has been worked from 65 deposits with 37 of those each producing over 1,000 oz. of gold.

The average tonnage and grade of these 37 deposits, according to a 1984 Nova Scotia Department of Mines and Energy report is given as 68,675 tons at a grade of 0.453 oz. per ton of gold. Seven of the deposits have each produced over 50,000 oz. of gold. The biggest producer, Goldenville, mined 448,428 short tons with an average gold grade of 0.469 oz. per ton and a total gold yield of 161,434 oz. Based on these figures, actual gold recovered from ore mined was 76.8%.

Current 1985 gold production in Nova Scotia is virtually nil. However, gold production could resume at a number of locations, which are described later in this report, if shown to be economically viable.

There has been limited gold production since 1980, notably at Cochrane Hill in the Sherbrooke area where 558 oz. of gold were produced* in a 100 t.p.d. direct cyanidation mill from 13,381 tons of open pit ore in 1981/1982.

From the 1860's until the 1940's when regular production ceased, gold was recovered in many mills using a combination of cyanidation and gravity concentration. The gold was extracted from the gravity concentrates by amalgamation after finer grinding. Depending on the minerology of each deposit, a varying amount of the gold was tied up in auriferous sulphides (mainly arsenopyrite). Recovery of gold from such sulphides by direct cyanidation leaching resulted in recoveries that did not exceed 70% and lime

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* N.S. Dept. of Mines and Energy Annual Report 1982/1983.

and cyanide consumption were high. Such a process today would result in severe environmental tailings problems both with residual cyanide and generation of acid in the tailings pond from oxidation of the fine sulphides over time.

A typical gold recovery process in the 1930's is described by E. O. Foster.* A batch cyanidation plant to leach gold from sulphide concentrates is described from the Ventures operation at Goldenville. The operation was barely economic on mill heads of 0.25 oz. per ton of gold. Such a process could not be used today without adequate environmental safeguards.

At all these properties gold occurs both free and associated intimately with arsenopyrite.

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* Guysborough Mines Ltd., Goldenville, N.S., Denver Trefoil M3-B5, 1941.

NATURE OF N.S. GOLD OCCURRENCES

1) Gold Deposits

From both historical data and current exploration, it appears that run of mine ore will be low grade (less than 0.10 oz. per ton of gold after dilution) with gold occurring in quartz stringers recoverable by gravity separation techniques and as inclusions in sulphides - mainly arsenopyrite. The overall gold content in either form would be highly variable since not all the quartz in run-of-mine ore would be auriferous. For example in the case of Goldenville, it is estimated by N. S. Dept. of Mines and Energy geologist Craig Miller that 10% of the quartz is auriferous.

At the Forest Hill deposit, Seabright geologists estimate from diamond drilling that reserves may total over 300,000 tons at 0.55 oz. per ton of gold at depths greater than 800 feet. However, due to mining dilution mill heads would probably be substantially lower.

Mine developer A. Hutchins estimates up to 1 million tons of ore at Beaver Dam with an average grade of 0.10 oz. per ton of gold occurring both free and associated with arsenopyrite. Mill feed, Hutchins estimates, could contain as much as 10% arsenopyrite, with 50% of the gold associated intimately with sulphides.

Several interviews were held with Dr. W. L. Young, President of Northumberland Mines Ltd., Goldenville Explorations Ltd., and Pan East Explorations. Dr. Young's companies are active in Nova Scotia whose properties include Cochrane Hill and Goldenville both currently optioned to Inco Ltd.

Pan East Explorations is drilling at 15 Mile Stream and drill core is currently being evaluated. The latter also has other N.S. gold properties under exploration in 1985.

At Cochrane Hill the open pit ore was amenable to conventional direct cyanidation after fine grinding to 80% minus 200 mesh since the gold occurs there in completely deformed amphibolite grains. There is metasedimentary rock adjacent to quartz veins and the sulphide content is relatively low. Gold recoveries up to 93% were obtained in a 100 t.p.d. mill. However, on mill heads of

0.06 oz. per ton of gold and milling costs over $20.00 per ton, direct cyanidation of finely ground ore at current gold prices is not economical. Later, pilot plant heap leach tests on ore crushed to minus 1" were encouraging with gold recoveries around 70% after 35 days. Current plans would be to install a vat leach plant on agglomerated ore crushed to minus 1/4" using a three-day leach and wash cycle. The cost to recover gold from a vat leach plant at Cochrane Hill has been calculated as $260 (Canadian) per oz. of gold* before taxes and depreciation.

In 1984, a 3,000 ton bulk sample was mined from an open pit at Goldenville. Approximately 2,000 tons of this sample were crushed and jigged at minus 1/2 inch in a permanent plant at a rate of 15 to 20 tons per hour. Good recoveries of both free gold and sulphides were made in the jig concentrate at a ratio of concentration of 1:25 by weight in the primary jig. Further work is planned on jig concentration in 1985.

Other significant gold occurrences in Nova Scotia include:

2) Old Mill Tailings

One company, Seabright Resources Ltd., has done much investigation of old gold tailings and through research done both at CANMET and Witteck Development shows that acceptable gold recoveries can be made by flotation. Although not economical at current prices, it is planned to build a portable plant to recover gold concentrates from selected tailings sites.

3) Beach and Off-Shore Deposits

From severe glaciation of gold-bearing outcrops, sampling has shown significant gold concentration along the East Coast of Nova Scotia. Seabright in their 1984 Annual Report summarize their exploration results from 330 claims at Country Harbour. Sampling

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* Maltby, P. Gold Production by Open Pit Mining and Vat Leaching at Cochrane Hill, N.S., 1983.

the sea bed showed gold values from 5 to 4250 ppb of gold by weight. However, economics and the future location of an off-shore natural gas line has put a hold on further development at this stage.

W. A. MacPherson of Mer Explorations describes work planned in 1985 on 600 acres of leased beach in the Harrington Cove area. Environmental permission with respect to fishing and wildlife safeguards has been obtained to proceed with sampling. Future production would be by a barge mounted treatment plant using screens and a Knelson gravity concentrator to recover gold values.

4) Lake Residues

In a discussion at N. S. Department of Mines and Energy with D. Murray, M. Grice and C. Miller, it was suggested that, through glaciation, significant gold values were concentrated in natural depressions - now lakes. Scraggy Lake in the Moose River area was suggested for sampling. No cottages or other development have taken place on this lake so that a dredging operation should be permitted without delay by the authorities. Some work on dredge development has been done recently by Canadian British Ltd., Halifax.

5) Basal Till - 15 Mile Stream Area

In an area of 1 sq. km., samples of basal till up to 2 metres thick have assayed less than 1 ppm of gold (average 0.002 oz. per ton). Till is covered with trees in a low lying wet area. Significant amounts of sulphides and ilmenite are present and it may be possible to concentrate gold in either a sulphide or ilmenite concentrate.

6) River Sediment - Meander River Near Windsor

Sampling of the river bed for gold was suggested since it was a natural depository for till.

7) Gold Associated with Base Metals

One area south of Antigonish holds potential for gold being present with copper values. Two such locations have been suggested - the Grantmire formation and Copper Lake. Drill core from the former is in storage at Stellarton (Department of Mines and Energy) which could be used to conduct bench scale beneficiation tests to test the potential for significant gold recovery, if economically justifiable.

8) Summary

In general, the writer prefers the gold potential of lake and river sediments and beach deposits. The uncertainty of sea water deposits is illustrated by the experience of a company called Matachewan which sampled sediments several years ago off the 'Ovens' near Lunenburg. After superpanning and assaying had indicated significant gold values, a further attempt to obtain samples 8 months later indicated that the entire deposit of up to 6 million cubic yards in 25 feet depth had disappeared, presumably moved by a combination of tides or storms or both.

As an example of the gold removed by erosion and glaciation in a deposit the size of Goldenville, Craig Miller estimated that up to 2,500 oz. of gold per foot of depth eroded is possible. These calculations were obtained by taking the overall gold area at Goldenville as being 12 million sq. ft. with 10% of the quartz present containing 0.5 oz. per ton of gold. The overall quartz content of the Goldenville deposit being 5% of the total rock volume. With 15 feet of till originally this gold removal by erosion from a deposit the size of Goldenville might have amounted to 30,000 oz. of gold. However, it is doubtful if even a fraction of this gold is present offshore to be recovered given the effect of tides, storms, and the solubility of gold over thousands of years in seawater.

In the writer's opinion the best chances of recovering even a small amount of gold lost to erosion lies in lake sediments and beach sands.

Not every gold deposit or those with gold potential have been mentioned by the writer. However it was possible to contact all the people connected with current N.S. mining activity. The types of deposits mentioned in this report cover the main gold occurrences currently being evaluated in Nova Scotia.

N. S. GOLD BENEFICIATION

General

From both historical and current geological data, run-of-mine gold ore from Nova Scotia will be:

1) from relatively small deposits (less than 1 million tons).
2) low grade - less than 0.10 oz. per ton of gold.
3) amenable to gravity concentration of crushed ore to recover a significant percentage of both the gold and sulphide values.

The percentage of gold intimately associated with sulphides will vary from deposit to deposit but it will be over 50% in most cases. The key to economic recovery from such deposits is the cost per oz. of gold recovered. At current gold prices gold mining and extraction costs before plant write-off, interest and taxes should not exceed $300.00 (Canadian) per oz. of gold recovered. In order to achieve such operating costs ore should be mined from an open pit or underground ramp and low capital and operating costs achieved by gravity concentration of crushed ore. High capital and labour intensive processes such as grinding, leach agitation and filtration on run-of-mine ore will not be economical except in exceptional circumstances. A generalized flowsheet is shown in Figure 1 which incorporates low cost beneficiation.

A recent report* for the N. S. Department of Mines and Energy concluded that Nova Scotia was the most attractive location for a regional processing facility in Canada and it is necessary for a successful gold mining industry in the Province.

The writer agrees with this in principal. However, from a practical perspective, mine operators prefer to do as much processing themselves and Nova Scotian deposits lend themselves to recovery of nuggety gold from gravity concentrates for sale directly to a Mint.

The basis for the report's conclusion was the fact that accessible but small gold deposits, which do not justify the

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* Davis, D.W.B.; MacKenzie, M.; Bilodeau, S. Effects of Location on Mine Development Potentials - N.S. Competitive Position in Canada, Centre for Resource Studies, May, 1985.

large investment required for an on-site processing plant, predominate the N. S. gold fields. This is true, but the writer was able to purchase and construct a crushing and gravity plant at Goldenville in 1984 which treated up to 20 tons per hour of feed rock for a total cost of under $200,000. This relatively small investment requiring two operators should be justified by all but the smallest deposits.

A central processing plant would thus treat sulphide concentrates containing at least 0.40 oz. per ton of gold which would justify the relatively high cost of trucking of $0.15 per ton mile (source: Seabright Resources Ltd.).

From an environmental viewpoint, all chemical processing would occur at the central plant, which would call for only one environmentally safe tailings storage area being required.

Central Processing Plant - 1985 Status

There is currently a proposal by Seabright Resources Limited to purchase the Gays River lead/zinc property from Esso Resources Ltd. and use half the 1350 t.p.d. mill capacity to produce lead and zinc concentrate from the re-opened mine, and to convert the other half of the mill capacity to treating both gold ore and concentrates. While not commenting on the economics of this plan, the Gays River area is a central location for a regional processing plant as shown in the accompanying map (Figure 2). For example, the construction of a sulphide roasting plant with calcine leach facilities and by-product facilities would be justified at Gays River for some of the following reasons:

1) The Gays River site has all services.
2) The tailings area at Gays River is a good one in a natural depression with many years available capacity (10 years @ 1350 tonnes/day). In addition, a large separate settling area exists 'downstream' from the tailings area which would make a good 'polishing' cell.
3) Tailings from a calcine leach plant would contain some base metals and cyanide. The large size of the tailings pond provides for a long residence time for optimum cyanide degradation.

4) The old Pb/Zn tailings are essentially limestone which will effectively neutralize any acid generated in a gold operation.

It is also proposed to build a fire assay laboratory at Gays River which would also be available for custom assaying. Such a facility is urgently required in the Province.

FIGURE 1: GENERAL TREATMENT SCHEME FOR NOVA SCOTIA GOLD ORES

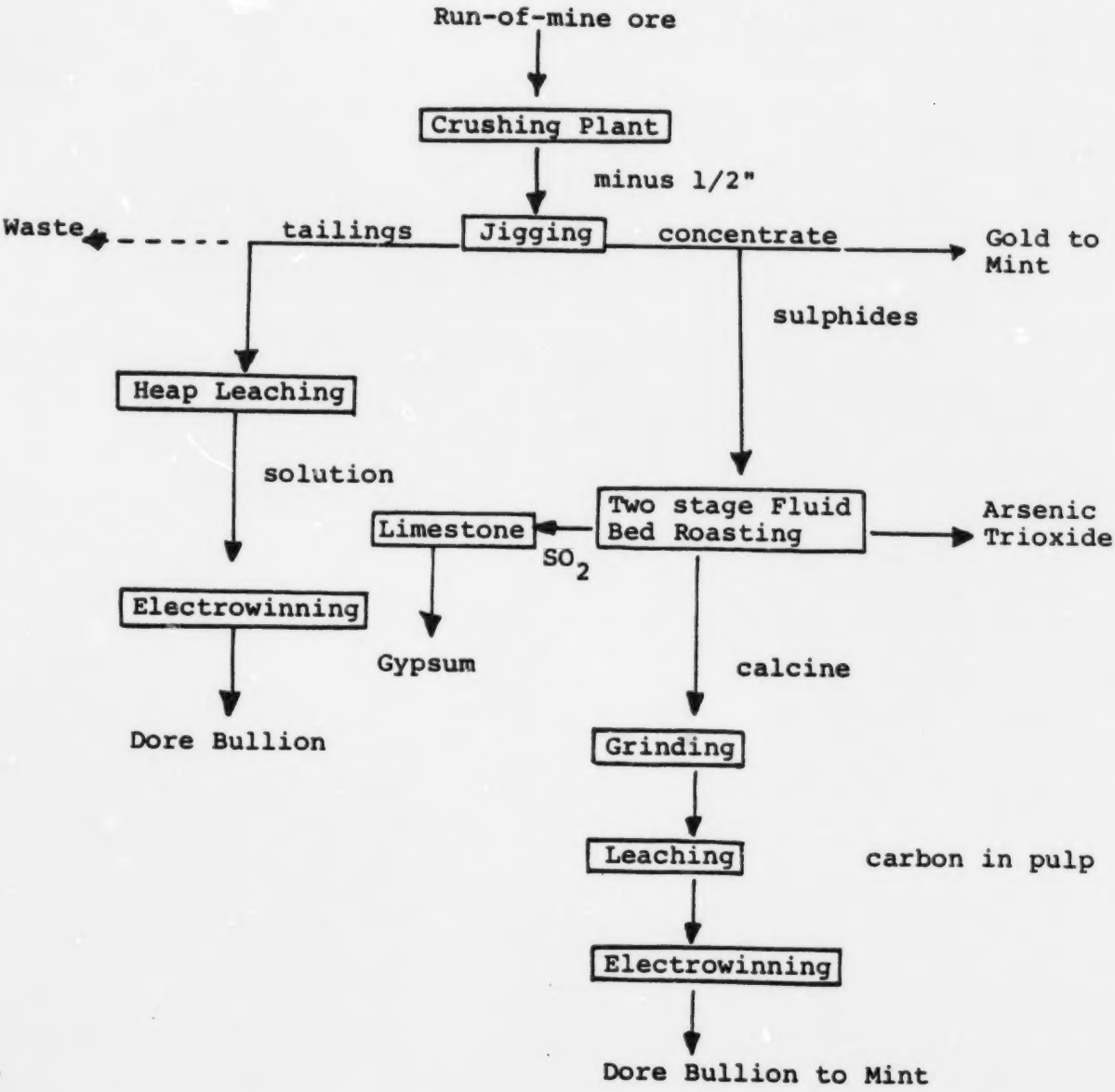
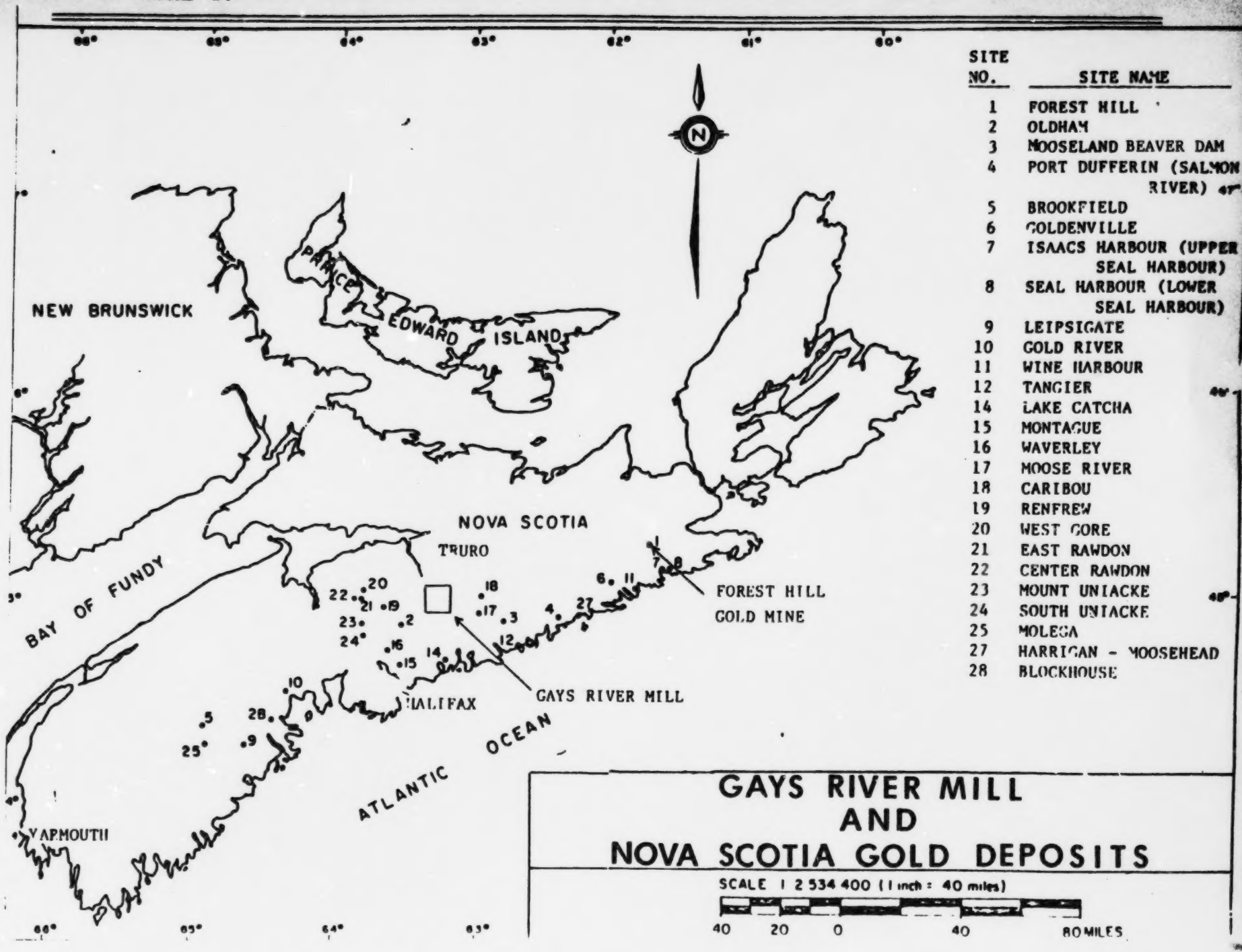


FIGURE 2:


NEW BRUNSWICK
PRINCE EDWARD ISLAND
NOVA SCOTIA
TRURO
BAY OF FUNDY
FOREST HILL GOLD MINE
GAYS RIVER MILL
HALIFAX
ATLANTIC OCEAN
YARMOUTH
N
SITE NO. SITE NAME
1 FOREST HILL
2 OLDHAM
3 MOOSELAND BEAVER DAM
4 PORT DUFFERIN (SALMON RIVER)
5 BROOKFIELD
6 GOLDENVILLE
7 ISAACS HARBOUR (UPPER SEAL HARBOUR)
8 SEAL HARBOUR (LOWER SEAL HARBOUR)
9 LEIPSIGATE
10 GOLD RIVER
11 WINE HARBOUR
12 TANGIER
14 LAKE CATCHA
15 MONTAGUE
16 WAVERLEY
17 MOOSE RIVER
18 CARIBOU
19 RENFREW
20 WEST GORE
21 EAST RAWDON
22 CENTER RAWDON
23 MOUNT UNIACKE
24 SOUTH UNIACKE
25 MOLEGA
27 HARRIGAN - MOOSEHEAD
28 BLOCKHOUSE
GAYS RIVER MILL AND NOVA SCOTIA GOLD DEPOSITS
SCALE 1 2 534 400 (1 inch = 40 miles)
40 20 0 40 80 MILES

RECOMMENDED R. AND D. PROJECTS

1) Roasting of Auriferous Sulphide Concentrate

Reasons for Roasting

The two main reasons for roasting auriferous N. S. sulphide concentrates are:

1) to free gold 'locked up' in the sulphide mineral which is mainly arsenopyrite, and
2) to remove minerals, chemical compounds and elements that interfere in the cyanidation leaching process.

Since the size of gold particles locked up in arsenopyrite may be less than 1 micron in size, roasting or aqueous oxidation is necessary to destroy the sulphides before leaching. Liberation by grinding is near the economic limit at about 40 microns. In addition, arsenopyrite decomposes to some extent in cyanide solution giving rise to compounds in solution that will inhibit the gold dissolution reaction. When arsenopyrite is agitated in a solution of lime (pH 10.5) in the presence of air (conditions required for gold cyanidation), alkaline arsenates are formed. This is a strongly deoxidizing reaction which results in a loss of dissolved oxygen from the leach solution, consequently, gold does not dissolve.

Chemistry of the Roasting Process

The roasting of sulphide concentrates may be defined as heating the sulphides in the presence of oxygen below the fusion points of the non-constituent minerals at such temperatures as to convert metallic sulphides to oxides. At the same time, a porous calcine containing gold is desired which will enable cyanide solution to come into contact with the gold and to dissolve it on subsequent leaching.

In roasting arsenopyrite, researchers agree that the higher the temperature employed in roasting the higher the gold losses in the leached calcine. In order to obtain good results, arseno-

pyrite must be volatilized preferably around 500°C. From production experience, optimum gold extraction is obtained when arsenopyrite roasting follows four distinct stages:

1) preheating;
2) arsenic distillation at 450-550°C;
3) oxidation of sulphides up to 600°C; and
4) cooling.

For this reason, current practice uses a two stage roasting procedure done in two fluid-bed reactors.

Since N. S. arsenopyrite is relatively coarse, it is well liberated by fine crushing and concentrate containing over 30% As can be achieved as roaster feed. Roaster feeds of this sulphide purity will roast better than feeds of lower sulphide tenure with more undesirable impurities such as iron silicates.

Calcine from Roasting

With careful control of roasting parameters, cyanidation of the ground calcine should yield gold recoveries in excess of 90%. The proposed R. and D. programme will establish the best gold recovery possible under pilot plant conditions.

R. and D. Programme

In order to establish a central sulphide roaster facility in Nova Scotia to treat auriferous sulphide concentrates consisting mainly of arsenopyrite, bench and pilot plant roasting tests should be done at a reputable laboratory under the supervision of competent consultants. A combination of Lakefield Research Ltd. and Fenco Engineers Inc. undertook recent roasting studies on an auriferous sulphide concentrate for Consolidated Professor Mines, Shoal Lake, Ontario. In a communication to the writer, W. Thoburn of Fenco indicated that the capital cost to construct a plant suitable for two-stage roasting of up to 50 t.p.d. arsenopyrite to produce saleable arsenic trioxide and a gold-bearing calcine would be about $5 million. A typical plant layout and flowsheet are shown in Figures 3 and 4.

Two-stage fluid bed roasting of auriferous arsenopyrite has been practised successfully for up to thirty years at two gold mines in Canada - Giant Yellowknife and Campbell Red Lake and since 1981, at Con Mine, Yellowknife. The process has been the subject of many papers.

A brief description of the roasting process is described: Wet ball mill closed circuit grinding of received sulphide concentrates to about 80% minus 200 mesh followed by storage in a thickener. The thickener underflow is then pumped at the required rate and pulp density to the first of two identical fluid bed roasters. Since the roast is exothermic, the only fuel needed is for the initial start-up. Calcine is collected from the second roaster hearth and the fine product from collecting cyclones. Calcine is quenched and is then pumped to the gold recovery circuit consisting of fine grinding, cyanide leach tanks, carbon adsorption, and electrowinning. The hot gases are cooled, and arsenic trioxide collected by electrostatic precipitators.

The final gas containing about 1% SO_2 may be vented to atmosphere using a 300' tall stack if local environmental permission can be obtained. If not, local limestone and/or dolomite may be used to convert the SO_2 to gypsum. About 2 tons of limestone is required per ton of SO_2. Alternatively SO_2 may be converted either to saleable liquid SO_2 or sulphuric acid if economically justified. Typical product weights, from roasting 20 t.p.d. of arsenopyrite, would be about 8 t.p.d. of SO_2 and 12 t.p.d. of AS_2O_3. Calcine containing gold for cyanidation would amount to about 10 t.p.d.

Arsenic Removal Efficiency

In order to determine the efficiency of arsenic removal from an arsenopyrite two-stage fluid bed roaster, Hatch Associates undertook a mass balance for arsenic from the roaster at Campbell Red Lake Gold Mines Ltd. in 1974.

The test results are shown in Table 1. Sampling was done deliberately in the summer since the warmer the ambient air, the more quench air is needed to achieve control temperature. The relative volume therefore of flue gas through the bag filter is at a maximum with consequent maximum emission of arsenic.

TABLE 1: ROASTER SAMPLING RESULTS ON ARSENIC

	Design		Test	
	Kg/hr	% of Feed	Kg/hr	% of Feed
Arsenic in Roaster Feed	222	100	155	100
Arsenic in Gas to Mixer	184	83	129	83
Arsenic in Stack Emission	6.8	3	0.7-1.6	0.5-1.0

From an arsenic emission rate of 0.24 kg/hour, the estimated maximum 1/2 hour ground level concentration is slightly less than 1 microgram per m^3. This was well below the Ontario criteria of 75 micrograms per m^3.

The Market for Arsenic Trioxide

From talks with marketing executives with Cominco and Boliden the annual world-wide market for arsenic trioxide is over 30,000 tons with producer prices about U.S. $0.30 per lb. or Can. $800.00 per ton. The main markets for arsenic trioxide are in insecticides, herbicides and wood preservatives. A 20 t.p.d. roaster in Nova Scotia could produce about 4,000 tons annually of arsenic trioxide worth $3 million. Assuming an average recoverable gold value in the roaster feed of $200 per ton or $3.5 million, the importance of the arsenic trioxide market is considerable for an economically viable operation. Nova Scotia would enjoy much lower transportation costs than current Canadian producers of arsenic trioxide in Northern Ontario and N.W.T. U.S. prices, imports and salient statistics for arsenic trioxide are

shown in Tables 2 and 3, and Figure 5 (source: U.S. Bureau of Mines).

Summary

In summary, an R. and D. roasting programme on auriferous arsenopyrite is proposed to establish capital and operating costs, and process parameters. Cyanidation leach tests would be done to recover gold from the calcine to determine costs and flow-sheet. An up to date marketing study on arsenic trioxide should be done to determine the price at which an output of 4,000 tons annually could be sold.

Direct cyanidation of arsenopyrite from Nova Scotia extracts less than 70% of the gold and results in excess cyanide consumption and fouling of solution with heavy metals and sulphur complexes. Excessive fouling leads in turn to the need for a heavy bleed stream and the resulting environmental problems with liquid waste disposal.

Roasting is a well proven and practiced solution.

Roasting References

1. Archibald, F.R. Roasting Arsenical Gold ores and concentrates. Can. Min. Metall. Bull., Vol. 42, 1949, pp. 129-139.
2. Matthews, O. Fluosolids Roasting of Arsenopyrite Concentrates at Cochenour-Willans. Can. Min. Metall. Bull., Vol. 42, 1949, pp. 178-187.
3. Wright, K.P. Fluid Bed Roasting in the Red Lake Camp. Can. Min. Metall. Bull., Vol. 54, 1961.
4. Spence, N.S. An Investigation of Gold Loss in Roasting Arsenopyrite Concentrates. E.M.J., Vol. 137, July, 1936, pp. 343-344.
5. Mortimer, J.M. and Tait, R.J.C. Flusolids Roasting Practice at Giant Yellowknife Gold Mines Ltd. Symposium on Application of Fluidizing Reactor. University of Arizona, 1959.
6. Rostron, D.W. Roasting of Pyrite or Arsenopyrite Concentrates for Gold Recovery. Randol Workshop, 1982.

FIGURE 3: ROASTING FLOWSHEET SCHEMATIC

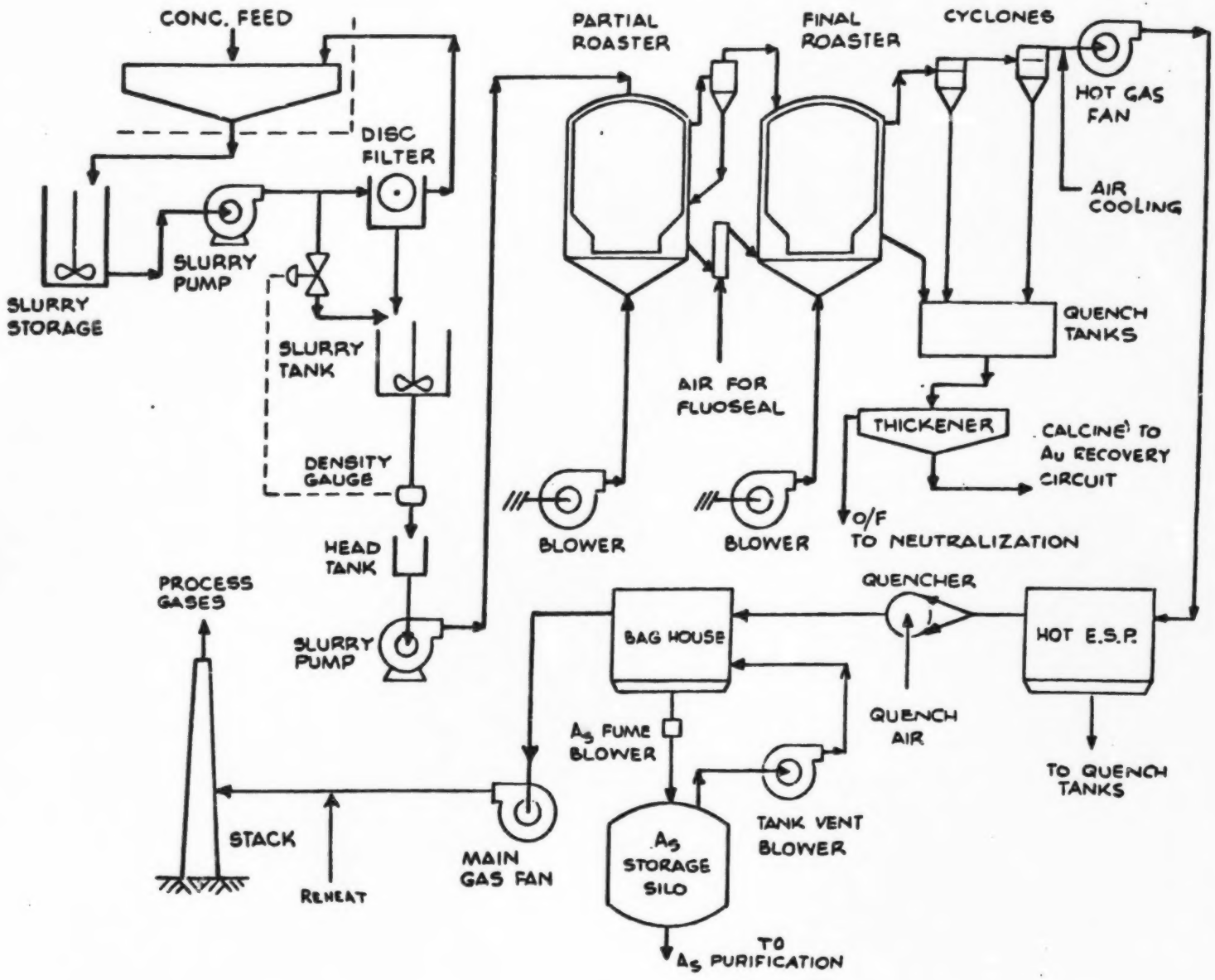


FIGURE 4: TYPICAL ROASTING PLANT LAYOUT

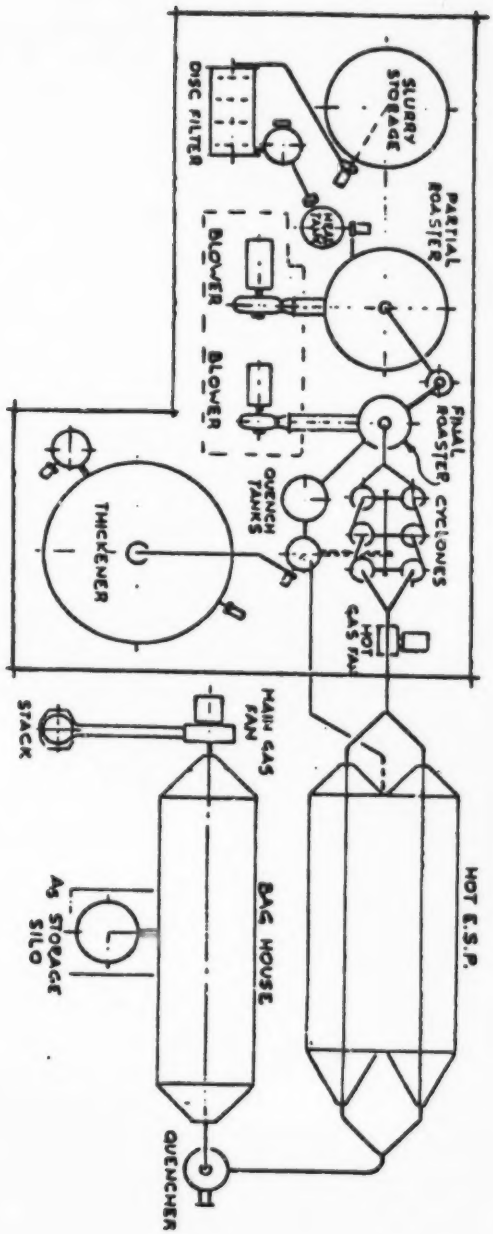


TABLE 2: U. S. PRICES OF ARSENIC TRIOXIDE

	¢/lb.		
	Domestic F.O.B. Tacoma 95% As_2O_3	Mexican F.O.B. Laredo, Tx. 99.13% As_2O_3	Imports 99.5% As_2O_3
1978	23.25	27	28-32
1979	24.25	30	32
1980	31.75	46	35
1981	40.0	78	45
1982	40.0	59	45
1983	33.0	45	N.A.

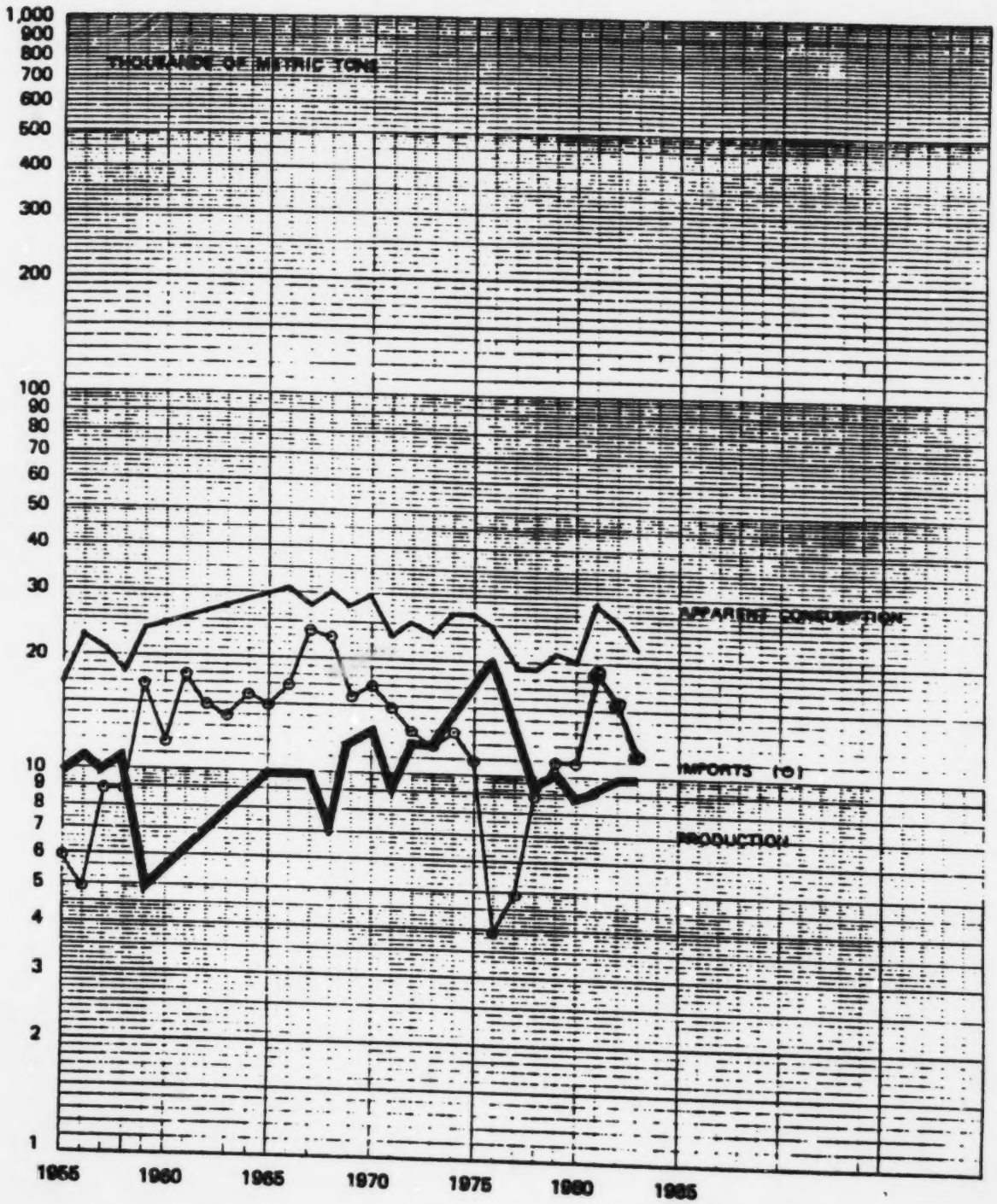
Source: U.S.B.M.

TABLE 3: U.S. IMPORTS OF ARSENIC TRIOXIDE (short tons)

	1980	1981	1982	1983
Canada	486	6,152	3,695	2,783
France	2,780	826	2,196	735
Sweden	4,770	5,403	4,620	3,781
Mexico	3,720	3,931	2,509	2,790
China	---	475	1,411	19
Belgium/Lux.	388	---	1,136	1,043
Others	384	751	524	78
Total	12,528	17,538	16,091	11,229

Source: U.S.B.M.

FIGURE 5: ARSENIC TRIOXIDE - SALIENT STATISTICS



Source: U.S.B.M.

2) Hydrometallurgical Treatment of Sulphides

Pressure Leaching

In considering the treatment of N.S. auriferous sulphide concentrate, pressure metallurgy is an alternative to roasting and should be the subject of an R. and D. project.

Several pressure oxidation processes exist as a means of decomposing arsenopyrite gold concentrates and date back about 30 years. Sherritt Gordon Mines Limited has extensive experience in pressure leaching and would be the preferred source for an R. and D. programme. Lurgi, Germany is also prominent in the field, having built a VAW tube digester at Randfontein to treat 40,000 tons per month of uranium feedstock.

In 1980 a patent was issued to Lakefield Research Ltd. describing a process whereby arsenopyrite concentrate may be treated with oxygen at a temperature below 120°C using a total pressure of 7-11 kg/cm^2. Arsenic is fixed as an acid insoluble iron arsenate which can be discarded in an environmentally acceptable manner. The concentrate remaining is then said to be amenable to cyanidation to recover gold. Any elemental sulphur formed must be removed before cyanidation.

Professor E. Peters of U.B.C. has invented a process for leaching arsenopyrite which has been assigned to Bacon, Donaldson and Associates Ltd., and is known as the Arseno Process. In a private communication, Dr. Peters states that the process performs well with arsenopyrite completely leached away, leaving gold bearing residues that permit easy recovery of all gold. Iron, arsenic and sulphur are precipitated from the solution in a second step as jarosites and ferric arsenate, free of gold and readily disposable. No arsenic or sulphur escapes to the environment.

Correspondence with Bacon Donaldson and Associates Ltd. elicited the following information: The Arseno process has modified the standard oxygen pressure leach by the addition of a catalyst. In the standard oxygen pressure leach conditions

vary between 180 and 200°C with pressures around 2000 kPa. Reaction times of the order of several hours are typical. Large autoclaves are required and designs must accommodate these severe conditions. In the Arseno process the addition of a catalyst promotes high reaction rates under mild oxygen pressure and at lower temperatures resulting in excellent gold recovery. The process claims decomposition of sulphides at a much faster rate under reasonable temperatures and pressures.

Atmospheric Leaching

Chemical treatment of arsenopyrite at normal atmospheric pressure prior to cyanidation have been claimed by various research organizations including ORF. For example, one method involves the treatment of concentrate with a sodium hydroxide solution. This is effective in rendering the sulphur soluble which can be separated by use of solid-liquid separation. However, iron arsenate is also formed and problems may arise in disposing of sodium arsenates, sodium polysulphides and unsaturated sulphur-oxygen compounds and iron hydroxides.

Witteck Development claims successful results on treating arsenopyrite with an atmospheric pre-oxidation leach using various oxidants followed by solid-liquid separation and cyanidation of the residue to extract gold.

Summary

To the writer's knowledge there are no commercial pressure leach plants in the world treating arsenopyrite concentrates to render them more amenable to gold recovery by cyanidation.

However, an R. and D. project is recommended for an initial period not to exceed 6 months using both a pressure leach and an atmospheric leach process to obtain process details, costs and estimates on gold recovery.

Reference: Bereowsky, R.M.G.S. and Weir, D.R. Pressure Hydrometallurgy - Its use in the Recovery of Uranium and Gold, October, 1982.

3) Bacterial Leaching of Sulphides

General

The use of bacteria and the development of new strains in unlocking gold trapped in sulphides is currently the subject of intense research in mineral laboratories around the world.

References of such work are listed below:

Gencor Ltd. of South Africa have developed specific strains of bacteria to attack arsenopyrite. It has not been possible to find out more specific information regarding these strains.

P. M. Mineral Leaching Technologies, Vancouver are reported to be developing a bacterial method as an alternative to roasting arsenopyrite. The Bio-Tank leach method, as it is called, can be done in small tanks at the mine site with treatment costs estimated at $55 per tonne for a 150 tonne per day capacity plant which includes capital write-off over 3 years. Concentrate is agitated from one to five days and bacteria breakdown the sulphides to form sulphuric acid which is drawn off and reused. The solid material left behind is then cyanided under alkaline pH conditions. Arsenic is oxidized during the leaching process and is left in an environmentally safe, insoluble form. A batch mode of operation is suggested.

The new strains of bacteria used are aimed at improving the economics of bacterial leaching such as faster rate of reaction at higher pulp densities.

Bacterial Heap Leaching

The bacterial process can also be used for heap leach operations on crushed ore agglomerated if required to improve permeability. At Mintek, South Africa, research on suitable binders, that must not consume acid or prove toxic to the bacteria if dissolved, has led to the conclusion that calcium sulphate is most effective in cementing fine sulphides.

The reaction releases heat which keeps a heap from freezing even at minus 40°C which should be more than enough for the Nova Scotia winters. The surface crust may freeze but the interior

temperature remains fairly constant. The bacteria are said to be highly adaptable and can be made resistant to cold or high levels of normally toxic elements such as arsenic or selenium.

It is suggested that an R. and D. project be initiated on 1) bacterial leaching of Nova Scotia gold-bearing sulphide concentrates and, 2) bacterial leaching of crushed low grade ore or gravity tailings containing small amounts of gold-bearing arsenopyrite and bacterial leaching of old gold tailings after agglomeration. Samples of all three feed sources are readily available. Some work on bacterial leaching has been done at Dalhousie (Geology Dept.). With adequate staffing, Atlantic Industrial Research Institute should be considered for R. and D. work on bacterial leaching.

References

Numerous B. C. Research publications - 1962 to 1982.

4) Mineralogical Studies By Image Analysis

It is proposed that an R. and D. project be initiated using automatic image analysis to study the occurrence of gold in samples from the Meguma Group.

Using scanning electron microscopy, energy dispersive X-ray analysers and the image analyser itself, when fully computerized, produce clean, high quality back scattered and secondary images for analysis in the original form. Developed by such workers as W. Petruk of CAN MET for each mineral in the sample, it is possible to determine its quantity, proportion occuring as fine particles, degree of locking of unliberated grains, size distributions of fine liberated particles, size distributions of unliberated mineral grains and surface exposure in unliberated grains.

When deciding on a gold recovery scheme, or looking for an answer to poor recovery, knowledge of the minerals in which gold is concentrated, as well as its grain size and associated minerals, will assist in the choice of the appropriate method. In the very

low concentrations in which gold exists in the Meguma Group, identification of gold bearing minerals are important in determining the recovery techniques. Examination of gravity tailings to identify gold losses would be a part of such a study. It is suspected by the writer that gold distribution in ore in the Meguma Group is similar throughout, but it would be useful to have confirmation of this using image analysis.

At a cost of about $500.00/sample, selectivity is important. It is suggested that a budget of $25,000.00 for a 12 month study would permit a detailed analysis be made on 50 selected samples.

Reference: Mainwaring, P.R. and Petruk, W. CAN MET. SEM based Automatic Image Analysis and its use in Mineral Beneficiation - A Review. Proceedings Scanning Electron Microscopy - SEM '84, Philadelphia, P.A., 1984.

5) Lake Bottom Residues

In a conversation with N. S. Dept. of Mines and Energy personnel, estimates were presented on the amount of gold removed by glaciation and erosion. Evidence of gold in offshore deposits and beach sands has been accumulated over the years. The uncertainty of offshore deposit stability with respect to storms and tides together with the environmental concerns for large scale exploitation of such deposits, rules them out as an R. and D. project at this time. With regard to beach sands, Mer Explorations is currently doing work around Harrigan Cove and it is not desirable to duplicate work.

Scraggy Lake was mentioned as a site for significant gold residue content. Located just south of Moose River gold mines and with no cottages on the lake, it is recommended that lake bottom samples be collected under the supervision of N. S. Dept. of Mines and Energy personnel for chemical analysis and beneficiation tests at the Atlantic Industrial Research Institute facilities. The writer has used these facilities and he is aware of the capabilities of some of the staff under Cyril Cole. In conducting R. and D. projects on N. S. gold benefication it would be desirable that some of the work be done at a N. S. facility.

Bench tests on Scraggy Lake residue samples involving size analysis, gravity, flotation and cyanidation should be done to determine gold content and beneficiation recovery. Estimates of the tonnage of lake residue should also be made.

6) Basal Till

A low grade source of gold on surface at 15 Mile Stream containing significant amounts of ilmenite was mentioned in discussions at the N. S. Dept. of Mines and Energy. The total deposit could amount to 2 million tonnes. An R. and D. project should be initiated, in conjunction with the Scraggy Lake residue project, to obtain representative samples of the basal till by N. S. Dept. of Mines and Energy personnel.

Chemical analysis and beneficiation tests, including magnetic separation, should be done.

If preliminary results are warranted, bench tests should be set up to develop a viable treatment scheme - for example, cyanidation heap leaching.

7) Meander River Sediment

If sampling of the river bed should yield significant gold values, chemical analysis and bench beneficiation tests should be done to find a means of concentrating such values.

CONCLUSIONS

Six specific R. and D. project descriptions, which relate to Nova Scotian gold processing, have been prepared for bids. These descriptions, which specify the methodology to be used, form six Appendices to this report.

In selecting these projects the writer has reviewed N.S. gold occurrences and processing history. Low cost, environmentally acceptable methods are recommended for primary concentration. The recommended R. and D. processes will also meet strict environmental safety requirements provided steps are taken either to market the by-products or to dispose of them in designated disposal sites.

The exact location of where test samples will be collected for R. and D. work is not defined in all cases - for example, low grade ore, gravity tailings and/or old tailings. Samples of each exist at Goldenville. However, other sample locations may also be considered for testing after discussions with government personnel.

APPENDIX 1: FLUID BED ROASTING

Methodology

An invitation to Tender for development of a Fluid Bed Roasting Process treating auriferous Nova Scotian sulphide concentrates with recovery of gold from the resulting calcine.

Historical

Since the roasting of arsenopyrite is considerably more difficult and complex than pyrite roasting, due to the detrimental influence of ferric arsenate ($FeAsO_4$ or $As_2O_5Fe_2O_3$), the roast should be done in two stages to minimize ferric arsenate formation. If this compound is permitted to form via high temperature and fully oxidizing conditions in the roast, gold extraction from the resultant calcine will be seriously inhibited.

Purpose

The purpose of roasting tests on N. S. auriferous arsenopyrite is:

1. to produce a calcine, containing all the gold in the roaster feed, which is amenable to cyanidation
2. to produce a marketable As_2O_3 product
3. to produce sufficient data for development of reliable capital and operating estimates for a production roasting facility.

All test data and recommendations are to be incorporated into a final report.

Test Conditions

Feed Preparation

Representative samples should be riffled out for roasting tests. Each roaster feed sample should be wet ball milled to about 80% minus 200 mesh and vacuum filtered. A small head sample should be taken from the filter cake for assay (Au, As, S, Fe, SiO_2) and size analysis. Wet filter cake should be repulped in water to the desired roaster feed density (about 75% solids by weight).

Roasting Conditions

1st Stage: Minimum practicable temperature should be used (approx. 500°C) with about 85% of the theoretical air so as to oxidize arsenic to arsenious oxide (As_2O_3) as a vapour and avoid the formation of As_2O_5 and ferric arsenate. The vapour should be sampled and analyzed for As_2O_3, oxygen, SO_2 after removal of all fine solids.

Time of the roast will be determined by on-stream gas analysis which will indicate when the first stage reaction has been completed.

2nd Stage: Complete the roast at 600°C using an excess of theoretical air requirements.

Collect samples of vapour, fines and calcine for analysis (Au, As, S). All gold assays are to be fire assay.

Number of Roasting Tests

In order to obtain optimum conditions it will be necessary to change certain variables and a total of 10 roasts should be allowed for in the price estimate.

Calcine

24 hour cyanidation tests are to be done on the wet ground calcine to provide data on gold recovery. The gold in solution should be adsorbed on activated carbon and Au assays done on the calcine head and leach residue, the loaded carbon, and the barren solution in order to calculate a mass balance. All reagent additions are to be recorded.

Roaster Gas Handling

Specific recommendations are required for the gas handling equipment to be incorporated in the design. Design points to be covered include: provisions against corrosion, instrumentation required, type of bags, calcine materials handling details,

As_2O_3 materials handling - prevention of sticking and prevention of cold spots using insulation and/or hot air jackets. Treatment of SO_2 by emission via stack and/or limestone adsorption.
The exhaust gas must be handled without leakage, and operated under negative pressure.

Cost Breakdown

A breakdown of costs into man-hours, analyses, overhead, supplies, office, typing etc. is required. Estimated time for completion - 6 months.

Reporting

It is anticipated that a consultant will periodically review all roasting tests. Bi-monthly progress reports will be prepared in order to facilitate the evaluation of tests costs, results and conclusions.

A final report will be prepared with all results and conclusions. Recommendations for further work should be made if warranted. Operating and capital cost estimates should also be included.

APPENDIX 2: PRESSURE LEACHING

An invitation to Tender for development of a pressure leaching process on auriferous Nova Scotian sulphide concentrates with recovery of gold from leach residues.

In order to develop a pressure leaching process to treat auriferous arsenopyrite concentrates, proposals should be sought from at least three sources: Lakefield Research, Sherritt-Gordon and Bacon Donaldson and Associates Ltd. (Arseno process) are suggested.

Methodology

The concentrates to be leached should be ground to about 80% minus 200 mesh and samples reacted under pressure to remove sulphur, arsenic and iron in solution in such a way, that the subsequent treatment of the concentrate to recover gold is feasible. In addition the salts in solution from pressure leaching must be preferably marketable and/or discardable in an environmentally safe manner.

The object of the test work is to develop a treatment scheme based on batch test work in which such variables as time, pressure, temperature, pH, reagent additions, oxygen and overall gold extraction are tabulated. From the results obtained capital and operating costs should be presented. Based on discussions of the bench scale test results and costs, a decision would be made whether to proceed with pilot plant tests.

Besides the overall metallurgical results obtained in pressure leaching, equipment recommendations are important with special reference to materials of construction for the pressure reactor, slurry pumps and seals, reactor linings and the system of heat transfer from discharge to feed slurry.

Mechanical problems have plagued pressure leaching development in the past so that attention to mechanical details at an early stage in testing is considered vital.

Reporting

It is anticipated that a consultant will periodically review all leaching tests. Bi-monthly progress reports will be prepared in order to facilitate the evaluation of test costs, results and conclusions.

A final report will be prepared containing all results and conclusions. Recommendations for further work should be made if warranted. Operating and capital cost estimates should also be included.

Cost Breakdown

A breakdown of costs into man-hours, analyses, overhead, supplies, office, typing, etc. is required together with a time schedule.

APPENDIX 3: ATMOSPHERIC OXIDATION LEACHING

An invitation to Tender for development of an oxidation atmospheric leach process on auriferous Nova Scotian sulphide concentrate with recovery of gold from the leach residue.

Methods which produce sufficient oxidation of auriferous arsenopyrite concentrates prior to cyanidation to improve gold extraction have been developed by several research organizations. These methods should be investigated and their potential evaluated for N.S. sulphide concentrates. Accordingly tenders to bid should be sent to Witteck Development Inc. and Ontario Research Foundation.

Methodology

Since a certain amount of secrecy presently surrounds these processes, research organizations should be invited to tender an R. and D. proposal disclosing the methodology they would propose to use.

Reporting

It is anticipated that a consultant will periodically review all leaching tests. Bi-monthly progress reports will be prepared in order to facilitate the evaluation of test costs, results and conclusions.

A final report will be prepared containing all results and conclusions. Recommendations for further work should be made if warranted. Operating and capital cost estimates should also be included.

Cost Breakdown

A breakdown of costs into man-hours, analyses, overhead, supplies, office, typing, etc., is required together with a time schedule.

APPENDIX 4: BACTERIAL LEACHING

An invitation to Tender for development of bacterial leaching on:

1) N. S. auriferous sulphide concentrates
2) N.S low grade ore or gravity tailings, and
3) N.S. old gold tailings with recovery of gold from the bacterial leach residues.

1) Sulphide Concentrates

Methodology

In order to investigate bacterial leaching of sulphide concentrates as a prior step to cyanidation, a Bio-Tank system should be investigated in which the concentrates are stirred under optimum conditions with the lixiviant.

Some of the variables to be investigated would include particle size, acid consumption, sulphur removal in days, pulp density, handling of waste products and conditions necessary for optimum gold recovery from the residues.

Factorially designed experiments are suggested. Best bacterial leach test conditions should be measured against the best gold extraction obtained using minimum reagent additions.

It is anticipated that a consultant will be present periodically to review progress. Bi-monthly progress reports will be prepared in order to facilitate the evaluation of test costs, results and conclusions.

A final report will be prepared including results and recommendations for pilot plant tests if warranted. Operating and capital cost estimates should also be included.

2) Crushed Low Grade Ore or Gravity Tailings and 3) Old Gold Tailings

Methodology

Because it is impractical for numerous large-scale heap leaches to be simulated in a laboratory and because of the scarcity of test

samples from undeveloped deposits, test work should be done in 3"-6" diameter plastic columns using about 3' depth of material to be leached. These columns are used so that the amenability of a material to bacterial heap leaching can be examined before testwork on a large scale is considered.

Lixiviant fed to the top of the column percolates through the test material and is collected at the base of the column. The chemical, physical and biological characteristics of the lixiviant should be known accurately, and changes in the composition of the recycled solution should be monitored at regular intervals so that the rate of sulphur extraction can be determined through the amount of soluble iron. The pH value of the reservoir of pregnant solution is maintained by frequent addition of acid.

A typical leaching campaign involves initial rapid irrigation with a sulphuric acid solution at a pH value of 1. This satisfies the requirements for inoculation of the column with bacterial cultures when the pH value of the pregnant solution is conducive to bacterial activity since high pH results in the death of acidophilic microbial species. Salts may be added to encourage bacterial activity and to enhance the dissolution rates of the minerals. After inoculation, the pH value of the recirculating solution should be maintained at about 2.5 - maximum bacterial activity occurs at this pH.

Observations from Bacterial Heap-Leaching Tests

While the concept of heap leaching is simple, failure can occur due to ignorance of leaching characteristics of the substrate or of aspects of heap construction and irrigation. Furthermore, the biological requirements of the bacteria must be satisfied. Bacterial activity within a heap may be inhibited by the following:

a) Poor aeration

Carbon dioxide and oxygen are essential to the metabolism, growth and reproduction of Thiobacillus.

b) Metal Toxicity

The concentrations of metal in the lixiviant must be maintained at levels below the toxicity threshold for the specific Thiobacillus culture used.

c) Availability of the Nutrient

Mineral surfaces occluded typically by ferric compounds may inhibit the attachment of the bacteria and reduce their access to essential ferrous ions and sulphur. In addition, points of localized alkalinity within a heap may lead to the hydrolysis of ferric iron and the formation of jarosite. This process may strip the lixiviant of essential nitrogen and potassium that are needed by the bacteria.

d) Temperature

Organisms of the Thiobacillus genus are mesophilic in character, and are limited to activity between 25 and 35°C. As the degradation of sulphide minerals in a heap is exothermic, a significant thermal gradient will arise that, at hot zones, will favour acid-leaching reactions to the detriment of the micro-organisms.

Some guidelines for heap-leaching experiments are suggested:

Particle Size: Low grade ore or gravity tailings crushed to minus 1/2" should be used.

Treatment of Fine Material: Agglomeration of fines results in enhanced permeability of the heap and the material to be leached which improves the rate of the leaching reaction by providing greater access to the lixiviant and the oxygen. Agglomeration may therefore be a variable for investigation. Calcium sulphate

has been found to be an effective binder under acid conditions.

Acid Consumption: Although sulphuric acid is generated indirectly by the activity of Thiobacillus, additional acid is required, particularly at the start of a bacterial heap-leaching operation. The presence of carbonate gangue would result in unacceptably high acid consumption so that the presence of carbonate should be monitored before undertaking test work.

Cyanidation

Following completion of bacterial activity, all acid solutions will be washed out and the samples subjected to alkaline cyanidation in the same column using normal test procedures. Gold would be adsorbed on activated carbon from the pregnant solution and the barren solutions adjusted with lime and cyanide. Sufficient samples would be assayed to obtain reliable mass balances.

Cost Breakdown

Show a breakdown of costs into man-hours, overhead, supplies, office, etc. Estimated time to complete the programme should be included.

Control of Testwork

It is anticipated that a consultant will be present periodically to review proposed methodology and monitor progress. Bimonthly progress reports will be prepared in order to facilitate the evaluation of test results and conclusions.

Final Report

A final report should be prepared including results and recommendations for field tests if warranted. Operating and capital cost estimates should also be included.

APPENDIX 5: MINERALOGICAL STUDIES BY IMAGE ANALYSIS

An invitation to Tender on mineralogical studies to determine the occurrence and distribution of gold on up to 40 samples from the Meguma Group of Nova Scotia.

Methodology

Deviations from the procedure described below are acceptable if of proven practice.

Sample Splitting

Each sample (after crushing and pulverizing) should be divided by a spinning riffle randomly into 8 small test tube receivers mounted on a rotating head. A final sub-sample of 200-300 mg is to be collected for particle sizes up to 150 µm, and proportionately more for larger sizes. The standard deviation of the final weights is typically 1-1.5% for sub-samples weighing from 10 g to 100 mg, and the sub-samples thus correspond closely to a statistically random selection of the parent populations.

Sample Mounting

For polished sections mounts of the sample particulates, it is desirable to avoid having the particles touch so that they can be recognized as individuals. It is also necessary to avoid segregation of the particles on the basis of mass or density. For these reasons, the particles are to be mechanically diluted and thoroughly mixed with 10:1 by volume of an inert filler of the same size range. Just sufficient epoxy is to be added to make the mixture fluid. It should then be allowed to set. During setting, the ore particles should be mechanically supported by the inert filler particles, and maintained in a random three-dimensional distribution.

Conventional polishing techniques are to be used on the cast sample blocks, except that after removal of the front face on a 220 grit diamond wheel, a further 300-500 µm are carefully removed by a one hour grind with powdered alumina on a cast iron lap prior to diamond polishing.

Operation of the SEM System

For full image information, the line spacing is to be made the same as the point spacing. The aim should be to distribute the measurements over the largest possible sample constituent with practicable measurement times.

Information Derived from SEM Measurements

For each sample, an image map of the minerals should be formed. In the case of particulates each separate particle should be located and defined by a boundary tracing procedure. Within each bounded particle the intercept lengths across each mineral should be summed to give mineral areas and are also to be used to give size distributions. For each mineral the number of contacts with other minerals are to be counted to define mineral associations. Area, perimeter length and maximum caliper diameter should be determined for each particle. This information should be interpreted on a particle-by-particle basis.

From the resulting sets of data the volume fractions, weight fractions, and elemental contents should be computed. Population statistics are to be determined with respect to mineral exposure sizes, particle sizes, surface areas, mineral associations, and additionally, for particles, intergrowth and liberation of selected minerals (gold and sulphides). The above computations should be made for each sample submitted for measurement.

Cost Breakdown

Show a breakdown of costs into man hours, overhead, supplies, office, etc. Estimated time to complete 40 samples - 6 months.

Reporting

Interim reports will be provided on a monthly basis as work proceeds.

A final report will be prepared listing all results with recommendations for further investigation if warranted.

APPENDIX 6: SAMPLING AND TESTING OF LAKE BOTTOM RESIDUE, BASAL TILL AND RIVER SEDIMENT

An invitation to Tender on sampling and testing of lake bottom residue, basal till, and river sediment to determine economic value by chemical analysis and bench mineral dressing tests.

Methodology

Samples would be collected by field crews from Scraggy Lake residue, 15 Mile Stream basal till, and Meander River sediment for chemical analysis, X-ray diffraction, and mineralogical studies using similar techniques described in Appendix 5.

It is expected that a consultant will be available to evaluate the results of analysis and determine whether to proceed with concentration tests. Such tests would include gravity, flotation, magnetic separation and hydrometallurgy on selected samples on a bench scale to develop the best flowsheet to be used to concentrate the metal values into marketable form.

The object of the test work therefore is:

1) to determine the overall value of each deposit, and
2) to develop a treatment flowsheet by bench scale tests of composite samples.

Cost Breakdown

Show a breakdown of costs into man hours, overhead, supplies, office, etc. Estimated time to complete the preliminary evaluation - 3 months.

Reporting

Interim reports will be provided bi-monthly as work proceeds. A final report will be prepared listing all results with recommendations for further investigation if warranted.

Control

It is anticipated that a consultant will periodically review progress through discussions and use of the progress reports.